TM / TC OVER CAN BUS: PRACTICAL APPLICATIONS

CAN IN SPACE WORKSHOP – JUNE 2019

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Date: 05/05/2019
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Template: 83230347-DOC-TAS-EN-006

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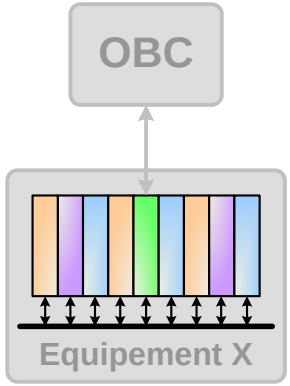
THE NEEDS (WISH LIST)

➢ TM/TC exchange on a bus:

- ➢ **Internal (backplane) or external bus**
- ➢ **Reliable & robust**
  - ➢ EMC friendly & tolerant
  - ➢ Differential with good common mode tolerance
- ➢ **Compatible with OBC data cycle (typ. 8~10 Hz)**
- ➢ **Simple & low cost**
  - ➢ Development & recurrent cost (BOM & tests)
- ➢ **Low power consumption**
- ➢ **Modularity**
  - ➢ Re-usable – Building blocks

- ➢ **Interoperability: NICE TO HAVE**
  - ➢ (helps validation)
  - ➢ For external buses

Internal:



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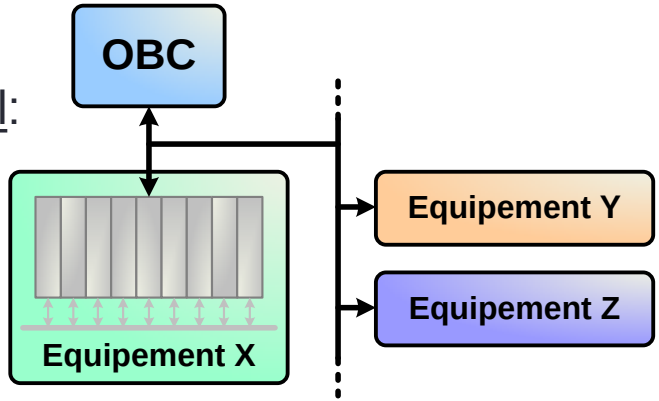

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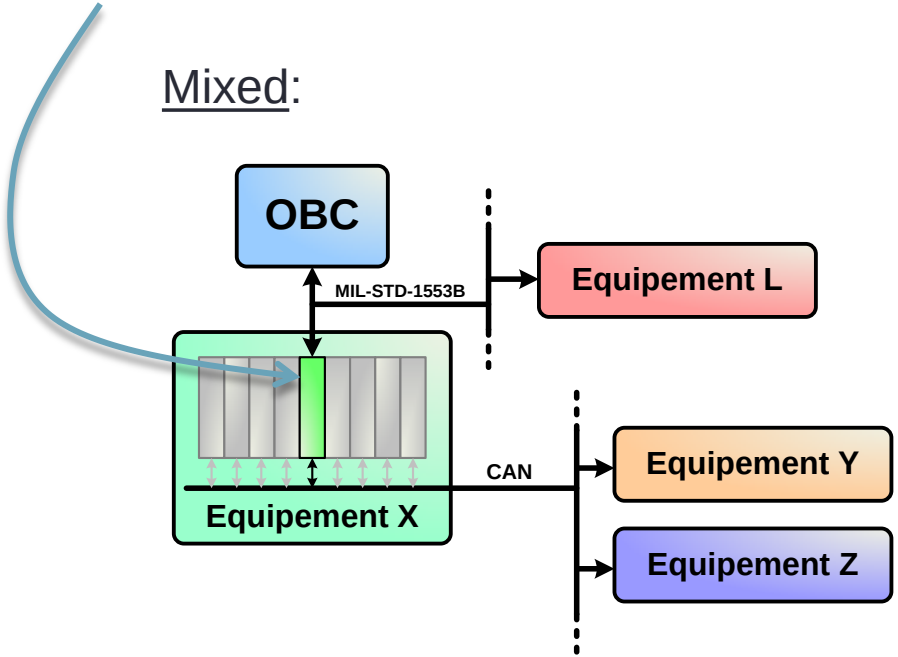
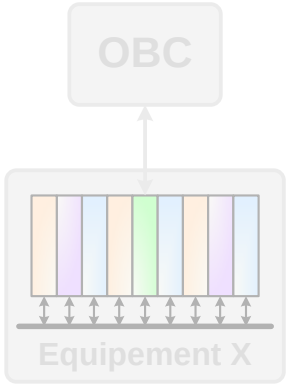
THE NEEDS (WISH LIST)

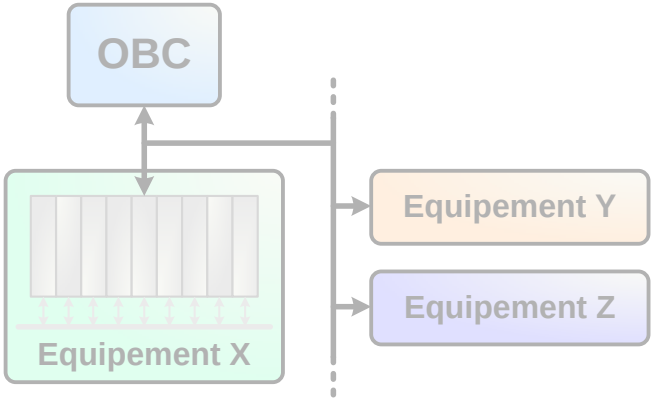
➢TM/TC exchange on a bus:

Protocol translation from legacy buses

Mixed:







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WHY CAN ?

➢ Good MIL-STD-1553B TM/TC bus replacement:

- ➢ Simple (two wires)
- ➢ EMC friendly (slow signal transitions – differential)
- ➢ Low power (slow – f.i. 20mW)
- ➢ Modular (layered protocol approach)
- ➢ Low cost
- ➢ Widely used (lots of components available, including 3V3 transceivers)
- ➢ Protocol features: synchro, time distribution, packet fragmentation, acknowledgment, …
- ➢ Interoperable (off-the-shelf tools available)

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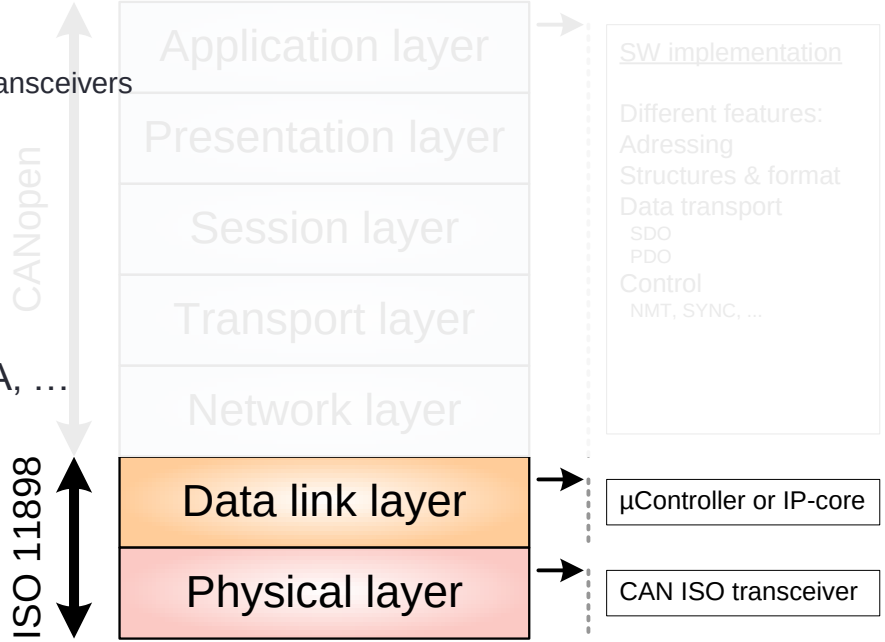
WHICH PROTOCOL ?

➢ PHY layer:

- ➢ ISO 11898 standard
- ➢ Handled by dedicated transceiver
  - ➢ Note: that min dominant V_{CAN_H} of 2.75V is too strict for 3V3 transceivers
    V_{diff} is OK (i.e. max dominant V_{CAN_L} reduced)

➢ Data link layer:

- ➢ ISO 11898 standard
- ➢ Handled by dedicated IP cores in ASIC, µC, FPGA, …



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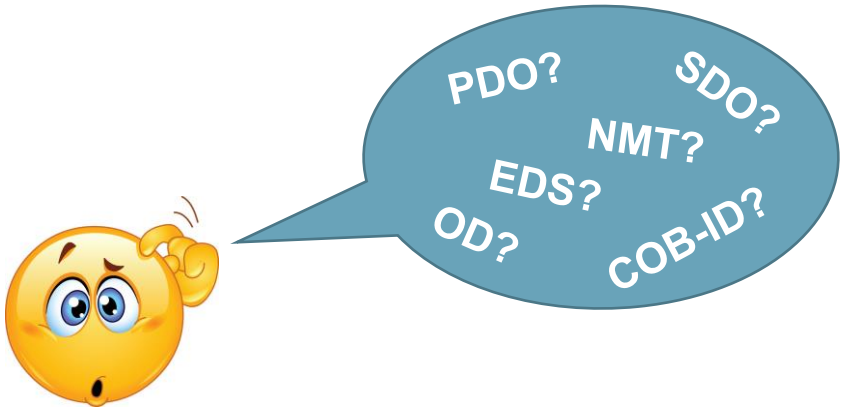
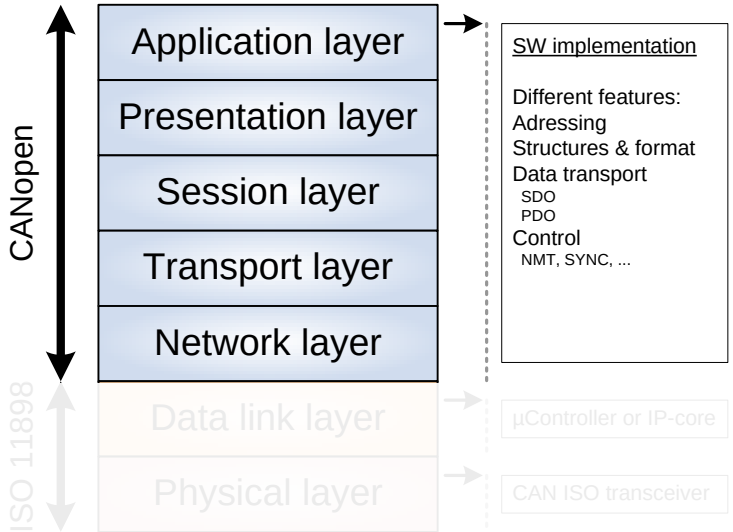
WHICH PROTOCOL ?

➢ Services upper layers:

- ➢ Applicable standards: CANopen / ECSS-E-ST-50-15C
- ➢ But… 1553 services were just fine:
  - ➢ Master-slave, fully deterministic, up to 32 x 16bits per message
- ➢ How to manage the transition ?
  - ➢ Keeping “1553 bridge” option





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THE PROTOCOLS

- **Wished:**
  - Compatible with legacy protocols (i.e. MIL-STD-1553B forwarding)
  - Fully deterministic
    - Compatible with OBC data cycle (8~10Hz)
    - Master / slave (no spontaneous slave transmission)
    - In case of error: no or controlled re-transmission
  - As simple as possible
    - To be implemented in mission critical qualified SW
    - Including bus monitoring & reconfiguration
  - Messages >8 bytes & acknowledge: optional (application dependent)

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THE PROTOCOLS

➢ Used in practice:

- ➢ Master/slave
- ➢ Time slots reserved for each master/slave transaction
  - ➢ In a frame synchronized with OBC data cycle
    - ➢ CANopen SYNC object
  - ➢ In case of transmission error: aborted if no room left
    - ➢ Note: must be supported by CAN controller
- ➢ CANopen:
  - ➢ SDO or PDO (statically mapped)
  - ➢ NMT heartbeat (by master)
  - ➢ COB-IDs

CANopen COB-IDs

Message type	Description	COB-ID
NMT	Network Management (broadcast)	0h
NMT Error Control	Network Management error control	701h – 77Fh
BOOT-UP	Boot-Up message	
SYNC	Synchronization message (broadcast)	80h
EMERGENCY	Emergency messages	81h – FFh
TIME STAMP	Time stamp (broadcast)	100h
PDO	Process Data Objects	181h – 57Fh
SDO	Service Data Objects	581h – 67Fh

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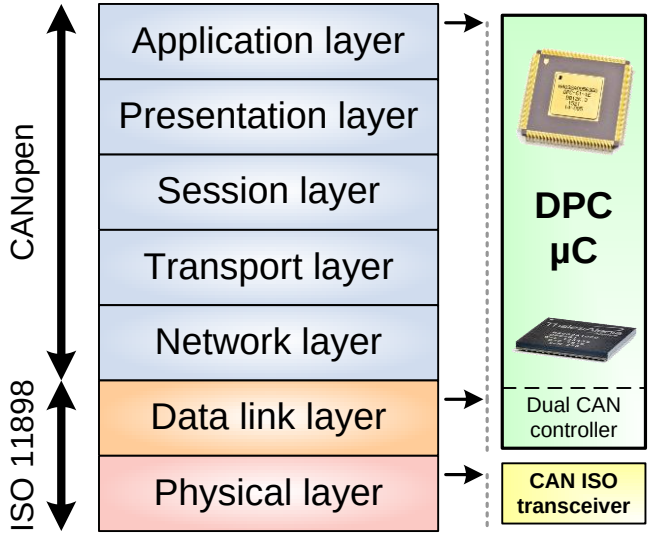
THE IMPLEMENTATION (TAS-B EQUIPMENT)

➢ PHY layer:

- ➢ Several transceivers available
  - ➢ Low latency & export constraints free preferred

➢ DATA & CANopen layers:

- ➢ “DPC” ASIC (Digital Programmable Controller)
  - ➢ 2 X CAN controllers for DATA layer
  - ➢ Dedicated µC core for communication protocols



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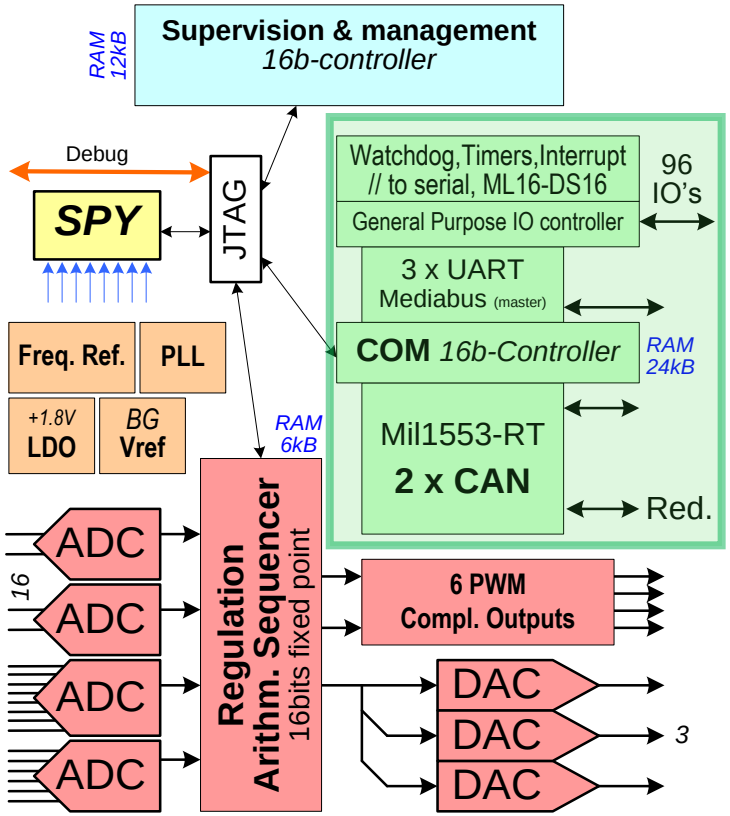
THE IMPLEMENTATION (TAS-B EQUIPMENT)

DPC ASIC:

- 3 x 16bits OpenMSP430 cores, 15 ↔ 60 MHz
  - Functions segregation
  - One core dedicated to communications
    - HW support for **CAN**, 1553, SPI, I²C, UART, …
  - One core dedicated to signal processing
    - 4 x 13bits 1Msps ADCs (16 inputs)
    - 3 x 12bits >1Msps DACs
  - One core dedicated to supervision & management
- >100 digital I/Os
- Built-in PLL & core power supply
- Full radhard
  - SEL > 78MeV.cm²/mg, SEU > 40MeV.cm²/mg
  - TID > 60krad(Si)
- No US export control constraint



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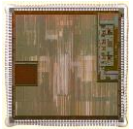
THE IMPLEMENTATION (TAS-B EQUIPMENT)

➢ DPC ASIC STATUS:

- ➢ **Silicon**: taped-out and first EM validations in 2013
  - ➢ More than 100h cyclotron test time (2015~2016)



- ➢ **CQFP package** (256 pins 0.5mm pitch):
  - ➢ Qualified according to ESCC9000 since Q1'2017 – TRL8
  - ➢ >400 FMs produced in June 2019 (and counting)
  - ➢ Used on >15 applications, in equipment like PCUs or PL/PFDIUs
    - ➢ TM/TC relay & conditioning
    - ➢ Power control (DC/DC, motor, PCU)

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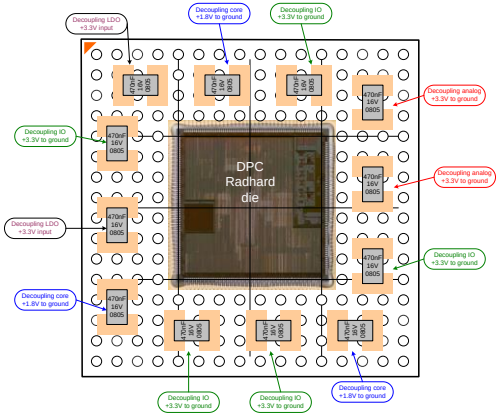
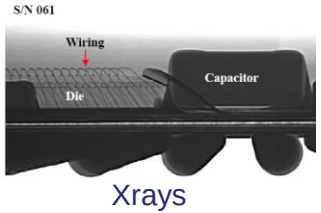
THE IMPLEMENTATION (TAS-B EQUIPMENT)

➢ DPC ASIC STATUS:

- ➢ **BGA package** (256 balls 1.27mm pitch):
  - ➢ For “new space” programs
  - ➢ Robust to thermal cycles
  - ➢ Significant cost and size reduction
  - ➢ Integrated power supply decoupling
  - ➢ Qualification ongoing (2020)
  - ➢ First usage: cubesat (OBC) OUFTI-2





Xrays

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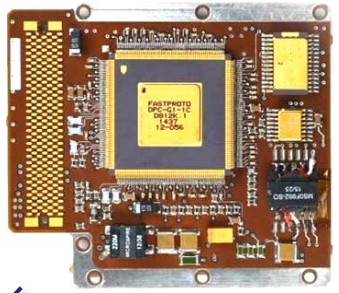
THE IMPLEMENTATION (TAS-B EQUIPMENT)

➢ DPC BUILDING BLOCKS:

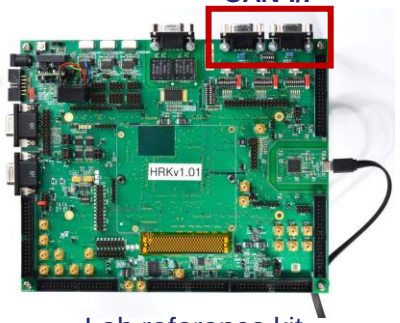
- ➢ Engineering cost/risk/planning optimization
- ➢ Several HW reference kits:
  - ➢ Lab grade, full equipped
  - ➢ Lab grade, light version (coming soon)
  - ➢ FM grade
  - ➢ All with embedded CAN transceivers
- ➢ HW reference functions
  - ➢ Including dual CAN interface
- ➢ FW reference functions
  - ➢ Including CANopen stack
    - ➢ PDO, SDO, …



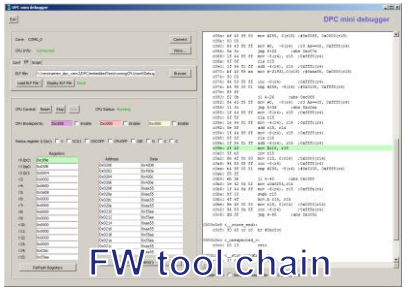
FM grade plugin module with CAN transceivers

FW functions library

CAN I/F



Lab reference kit



FW tool chain

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CAN: CONCLUSIONS

➢ CAN MEET TM/TC REQUIREMENTS:

- ➢ Flexible
- ➢ Simple, low power
- ➢ Low engineering & BOM cost
- ➢ EMC friendly

- ➢ Improvement paths ?
  - ➢ Galvanic isolation in transceivers (with low additional delay)
  - ➢ Spontaneous slave transmission allowed

- ➢ Thank you !

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